SYSTEMS AND METHODS FOR MONITORING AND CONTROLLING WATER CONSUMPTION

This application is a continuation-in-part of U.S. Utility Application Serial No. 10/252,350 filed 23 September 2002.

BACKGROUND OF THE INVENTION:

1. Field of the Invention

The present invention relates to the fluid consumption systems in the home and commercial environments. More particularly, the invention relates to automated controls and monitoring of such water-based systems employing methods for detecting, communicating and preventing operational failures.

2. Description of the Related Art

There are various water-consuming fixtures, appliances, and systems in both residential and commercial installations. Typical water-based systems include sinks, toilets, dishwashers, washing machines, water heaters, lawn sprinklers, swimming pools and the like. For example, hot water tanks include a heating element located at the bottom of the tank, with a hot water outlet pipe and a make-up water inlet pipe connected through the top of the tank. In water tanks a thermostat is generally included for setting the desired temperature of the hot water withdrawn from the tank, and typically a blow-out outlet is connected through a pressure relief valve to allow hot air, steam and hot water to be removed from the tank through the relief valve when the pressure exceeds the setting of the relief valve. The relief valve may be periodically operated for relatively short intervals during the normal operation of the hot water tank. This allows bubbling steam and water to pass through the relief valve for discharge. Once the pressure drops below the setting of the relief valve, it turns off and normal operation of the hot water tank resumes.

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After a period of time, however, mineral deposit buildup and corrosion frequently take place in relief valves and the like, as a result of these periodic operations. In time, such corrosion or scale build up may impair operation. When this occurs, the possibility of a catastrophic failure exists. In addition to the possibility of high pressure explosions taking place in water tanks, other conditions can also lead to significant damage to the surrounding structure. As hot water tanks age, frequently they develop leaks, or leaks develop in the water inlet pipe or hot water outlet pipe to the tank. If such leaks go undetected, water damage from the leak to the surrounding building structure results.

U.S. Patent No. 5,240,022 to Franklin discloses a sensor system, utilized in conjunction with hot water tanks designed to shut off the water supply in response to the detection of water leaks. In addition, the Franklin patent includes multiple parallel-operated sensors, operating through an electronic control system, to either turn off the main water supply or individual water supplies to different appliances, such as the hot water heater tank.

The U.S. Patent No. 3,154,248 to Fulton discloses a temperature control relief valve operating in conjunction with an over heating/pressure relief sensor to remove or disconnect the heat source from a hot water tank when excess temperature is sensed. The temperature sensor of U.S. Patent 4,381,075 to Cargill et al. is designed to be either the primary control or a backup control with the pressure relief valve. Three other United States patents, to Lenoir No. 5,632,302; Salvucci No. 6,084,520; and Zeke No. 6,276,309, all disclose safety systems for use in conjunction with a hot water tank. The systems of these patents all include sensors which operate in response to leaked water to close the water supply valve to the hot water tank. The systems disclosed in the Salvucci and Zeke patents also employ the

sensing of leaked water to shut off either the gas supply or the electrical supply to the hot water tank, thereby removing the heat source as well as the supply water to the hot water tank. The U.S. Patent No. 3,961,156 to Patton utilizes sensing of the operation of the standard pressure relief valve of a hot water tank to also operate a microswitch to break the circuit to the heating element of the hot water tank.

While the various systems disclosed in the prior art patents discussed above function to sense potential malfunctioning of a hot water tank to either turn off the water supply, the energy supply, or both, to prevent further damage, none of the systems disclosed in these patents are directed to a safety system for monitoring potentially damaging pressure increases in the hot water tank in the event that the pressure relief valve malfunctions. This potential condition, however, is one which is capable of producing catastrophic damage to the structure in the vicinity of the hot water tank.

An improved water sensor unit would be desirable wherein a plurality of water-related appliances or equipment can be simultaneously monitored and, in the event of sensing water with respect to any one of the several items being monitored, appropriate action is taken, such as shutting off the power to the unit and simultaneously shutting off the water supply to that particular unit.

U.S. Patent No. 5,428,347 to Barron shows a water monitoring system with minimal expansion and protection capabilities. The input and outputs (I/O) offered by the system limit the number of water appliances individually protected. The Barron device was designed such that a normal installation would use a single control unit. The number and types of inputs suggest it was designed primarily to protect a single water heater, and to act as an external control unit for an air conditioner. A number of auxillary devices could be protected using an auxillary

water sensor input. Outputs provide for control of a hot water solenoid, a cold water solenoid, three alarm signals for external buzzers or bells and an optional external air conditioner control unit. This requires that the unit control be a single standard 24vac water control valve for the main hot water in feed and the main cold water in feed line. Thus, it can cut off the power to the unit that tripped the alarm. No matter which sensor is triggered, it appears the unit can only cut off the main water in feed line(s) to the home and can only remove power from the unit plugged in to it. However, the unit does not have a one-to-one correspondence between a sensor and a control valve. The valve control outputs are wired such that if any one of the units sense a water leak, it could close the valves.

It is desirable to provide a water consumption monitoring system which overcomes the disadvantages of the prior art, which is capable of monitoring one or more water consumption parameters of water-based systems that may be installed with an after-market add on, or which may be incorporated into original equipment, and which further includes the capability of remote monitoring of branches or areas of the water-based systems.

SUMMARY OF THE INVENTION:

The invention is designed to monitor and control the daily water consumption flow of all water-based systems in the home or commercial business. These include, for example, water heater, sinks, toilets, dishwashers and clothes washer, swimming pool and lawn sprinklers. The invention includes one or more electrical circuit interface modules in an electrical panel, or motherboard, and each interface module "protects" a branch or area of the home or business from electrical overload or malfunction. The interface module motherboard also "protects" a branch or area of the home or business. The electrical interface module offers protection from

electrical malfunction and protection from water/liquid based overloads or malfunctions.

A motherboard design includes single or dual microcontrollers, user interface, USB port for Web/network interface, video interface, and provisions for up to sixteen interface modules. One interface module acts as a main shut off valve and controls flow meter expansion connectors, power supply, sealed lead-acid battery backup with charger. Modular in design, the interface module is based on two separate printed circuit boards (PCBs). Up to sixteen interface modules are plugged into the motherboard. Each interface module is connected to one or more water leak sensors that detect water leaks or levels, and a control valve used to control the associated water in feed. When an interface module is used as a water leak sensor, it is attached to the water heater and connected to an interface module. A cutoff valve is attached to the water in feed of the water heater and connected to the same interface module. The motherboard microcontroller monitors the water leak sensor. If the microcontroller detects a leak, it closes the control valve and issues an alarm. An interface module can also be used to monitor the level of water in such items as a swimming pool. A water level detector is attached to the swimming pool along with a control valve that controls the water in feed to the pool. When the microcontroller detects a low level condition, it opens the in control valve and adds water to the pool until the level is normal. Each interface module can operate with direct wire connection, to the N/O or N/C valve and sensor. Individual interface modules can also transmit or receive wireless data, between the valve and sensor directly to the interface module. The interface modules can also be operated in a timed mode or sensor mode. This allows the user to set multiple on/off times for the control valves. This allows the system to control a lawn sprinkler on and off at any given time.

The interface module system motherboard and control panel is a web appliance. It includes a standard 10-mega-byte Ethernet TCP/IP connection. This allows it to be connected to either a local area network (LAN) or a wide area network (WAN) such as the World Wide Web. The web connection is used for configuring the interface module system via a remote PC connected to the same network (LAN or WAN). It is also used to communicate alarm warnings to those parties of interest via standard simple mail transfer protocol (SMTP) e-mail. Alarm e-mails can be sent to multiple addresses such as the home, homeowner's office, a cell phone, or even the plumber.

The interface module system also has the capability to host a web page on the Internet. This allows the owner or security service to monitor the status of all water facilities in a home or business remotely. The web page can be configured to provide remote operation and control. That is, remote commands can be issued by clicking controls on the web page. As an example, the owner of a home could shut off the main water feed remotely.

The interface module supports a video uplink. It provides sixteen standard RCA video input connectors, one for each interface module. Small low cost video cameras can be plugged in and aligned to show a picture of each water appliance. The alarm e-mail can be setup to include a .jpg video image as an attachment. The picture can be used without the network interface. The motherboard provides a graphic vacuum florescent display (VFD) and a keypad. The display and keypad can be used to setup, configure, and operate the system even during power failures. A sealed lead-acid battery provides power for the system during power failure. The motherboard includes an onboard buzzer to signal alarm conditions. In addition, it

provides a connection for one or more external alarm buzzers. These can be located around the home or business.

It is another object of this invention to provide a water monitoring system which turns off the water supply and the energy supply to a water appliance or system upon the sensing of one or more parameters of operation of the water appliance or system. It is an additional object of this invention to provide a monitoring system for sensing excess pressure in a water appliance or system to shut off the water supply to the appliance or system and to shut off the energy supply to it.

It is a further object of this invention to provide a monitoring system including a pressure sensor located to sense the pressure variations of the water appliance or system without water flow through the pressure sensor to provide an output for shutting off the water supply and/or the energy supply to the heating unit of the water appliance or system when excess pressure is sensed.

Briefly summarized, the present invention relates to systems and methods for monitoring and controlling water consumption using one or more sensors in a water-based system for generating signals indicative of the operation thereof. One or more interface modules are provided as breaker circuits for receiving the generated signals, and a fluid control device is operable for limiting the water consumption. A motherboard receives the interface modules and provides communication there between for information processing. Signals from the various sensors are supplied to a controller, which provides signals to status indicators, and also operates to provide alarm signals via network interfaces to remote locations and to operate an alarm. In an alternate embodiment a monitoring system is designed to shut off the water supply to a water appliance or system and to shut off either the electrical

supply or the gas supply to the heating unit of the water appliance or system in response to sensing of malfunction of one or more of a number of different sensed parameters. These parameters include a water leak detector located beneath the water appliance, a water level float sensor, a temperature sensor to sense excess temperature, and a pressure sensor located in line.

In accordance with one embodiment of the invention, a monitoring system having an input water supply, an output water line and a source of heat energy is provided. The system includes a pressure sensor connected to sense the pressure inside the appliance or system and provide an output signal when the sensed pressure exceeds a predetermined threshold. Additional sensors also may be provided to respond to one or more additional operating parameters of the appliance or system, including excess temperature, water level, and water leaks to provide additional output signals whenever a senses parameter reaches a predetermined threshold. A valve is located in the input water supply. A control for disconnecting the source of heat energy from the water appliance or system is also provided. A controller is coupled to receive output signals from the pressure sensor and the additional parameter sensors, if any, and operates in response to an output signal from a sensor to close the valve in the water supply line, and to cause the source of heat energy to be disconnected from the water appliance or system.

BRIEF DESCRIPTION OF THE DRAWINGS:

Figure 1A is a block diagram of a first embodiment of the invention;

Figure 1B is a block diagram of a second embodiment of the invention;

Figure 2 is a detail of a portion of the embodiment shown in Figure 1A;

Figures 3A and 3B together comprise a more detailed circuit block diagram of the first embodiment of the invention;

Figure 4 is a schematic diagram showing circuitry for an interface module for the embodiment shown in Figure 1B, providing breaker circuitry that monitors and controls water consumption in accordance with the invention;

Figure 5 shows the interface module motherboard including master-slave microcontrollers;

Figures 6A, B, C and D show eight (8) additional slave microcontrollers provided on the motherboard of Figure 5;

Figure 7 is a schematic diagram showing alarm enunciation devices used for indicating alarm conditions and the like;

Figures 8 and 9 show power and battery backup circuitry, respectively, for the monitoring and controlling circuitry of the described system;

Figure 10 shows the interface module "breaker" housing for the circuity of Figure 4, providing breaker circuitry that monitors and controls water consumption in accordance with the invention; and

Figure 11 shows the panel housing for the motherboard of Figure 5 to receive a plurality of interface modules.

<u>DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS</u>:

Reference now should be made to the drawings, in which the same reference numbers are used throughout the different figures to designate the same or similar components. Figures 1A and B are block diagrams of water monitoring systems providing comprehensive monitoring of various alarm conditions representative of malfunctioning parameters in water-based systems and the like. In addition, the system of Figure 1A operates in response to a water appliance or system malfunction to turn off the input water supply and to disconnect the energy source supplying heat to the water appliance or system when such a malfunction occurs.

In the monitoring system shown in Figure 1A, a hot water tank 10, which may be of any conventional type, is illustrated. The hot water tank 10 may be heated either by a gas supply or an electric supply. The system operates in the same manner, irrespective of which type of heat source is employed for the hot water tank 10. Inlet or make-up water for the hot water tank 10 is supplied through an inlet supply pipe 12 through an electrically operated valve 14, from a water inlet pipe 16. The heating energy is supplied, either through a gas pipe or through electrical lines 18, through a gas shut-off valve 20 (or alternatively, an electric power switch 20), with gas/electric power input being supplied through a gas pipe 22 (or suitable electrical leads).

Hot water produced by the tank is supplied to a water output pipe 24 in a conventional manner. The final portions of the hot water tank system include a blow-out pipe or outlet 26, which is connected to a conventional pressure relief valve 28, designed to relieve pressure in the tank 10 when the internal tank pressure exceeds a predetermined amount. Such a blow-out outlet 26 and relief valve 28 are conventional.

In the remainder of the system shown in Figure 1A, various parameter sensors are connected to a central controller 30 for providing indicia representative of the operating condition of the water tank, and for sensing different parameters of the operation of the water tank 10. If the parameters either exceed some pre-established threshold or indicate a condition which is indicative of a failure of the hot water tank 10, a signal is sent to the controller 30, which then operates to provide outputs indicative of the status of the water tank operation, and, in addition, operates to turn off the water supply to the tank and turn off the source of heat energy to the tank 10.

As indicated in Figure 1A, one of the parameter sensors is a water leak detector 32. This is indicated diagrammatically in Figure 1, with a pair of contacts shown located beneath the water tank 10. A suitable container (not shown) to catch water leaks from the water tank 10 and the pipes 12 and 24 may be provided. When the water level becomes sufficient to bridge the contacts which are shown extending from the leak sensor 32, it provides a signal to the controller 30 indicative that a leak, either from the water tank 10 itself or from the supply pipe 12 or the water outlet pipe 24, in the vicinity of the hot water tank 10, has occurred. The signal sent to the controller 30 then is processed to place the system in its alarm and safety shut down mode. Also shown in Figure 1 is a float sensor 34 to provide an indication that the water level within the tank 10 has dropped below a safe level. The output from the float sensor 34 is supplied to the controller 30 to cause it to operate in a manner similar to the response to the leak sensor 32.

In addition to the generally conventional leak sensor 32 and float sensor 34, the hot water tank system shown in Figure 1A has been modified in the region of the connection to the hot water tank at 26 for the pressure relief valve 28 to employ two additional branches to sense parameters at the blow-out outlet 26. One of these is to sense temperature through a branch or leg 40 coupled with the pipe 28. A temperature sensor 36 is provided in the branch 40. A pressure sensor 38 is coupled through a branch or leg 42 to the blow-out relief valve line 26. The outputs of the temperature sensor 36 and the pressure sensor 38 also are supplied to the controller 30, as indicative of a temperature exceeding a safe operating temperature (as determined by the manufacturer of the hot water tank 10) and by sensing through the pressure sensor 38 a pressure in excess of a safe threshold (again, determined by the manufacturer of the hot water tank 10) to supply signals to the controller 30.

Thus, the sensors 32, 34, 36 and 38 all supply 8 independent malfunction signals, depending upon the parameter being sensed, to the controller 30 to cause it to operate whenever one of the hot water tank malfunctions occurs.

Ideally, the pressure sensor 38 is selected to provide a signal to the controller 30 at a pressure slightly above the pressure which normally would operate the relief valve 28 for the hot water tank 10. Thus, the safety system operates prior to a condition which causes the relief valve 28 to operate.

The controller 30 is supplied with operating power from a suitable power supply 52, supplied with input from an alternating current input 50. The power supply 52 is shown in Figure 1A as supplying positive and negative DC power over lines 54 and 56, respectively. It should be noted, however, that DC power levels at other voltage levels also may be obtained from the power supply 52 for operating various electronic circuits and sub-circuits through the controller 30. Operating power also is supplied, as indicated in Figure 1A, over the positive DC power lead 54 to an LED status indicator 60. The LED status indicator 60 has at least two output status lights in the form of LED lamps 62 and 64 located in a convenient location for a home owner or maintenance person to obtain a quick visual check of the status of the hot water heater 10. Under normal conditions, with no outputs from any of the sensors 32, 34, 36 and 38, the controller 30 sends a signal to the LED status indicator 60 to illuminate a green LED light 62. In the event that anyone or more of the sensors should supply an alarm signal to the controller 30, a signal is sent from the controller 30 to the LED status indicator 60 to turn off the green LED 62 and to illuminate a red LED 64. This indicates to a person checking on the water heater 10, either at the location of the water heater 10 or at a remote location where the LED status indicator 60 may be located, the operating condition of the water heater 10.

If an alarm condition occurs, the controller 30 also sends signals to the electric shut-off valve 14 to turn off the water supply through the inlet pipe 16, and a signal to the gas/electric shut-off valve switch 20 to turn off the supply of gas or electricity to the heating element of the water heater 10. Consequently, no water is supplied to the water tank 10 and the source of heat is removed, thereby establishing as safe as possible a condition for the environment around the hot water heater 10 whenever an alarm condition exists.

At the same time, the controller 30 also may operate one or more alarms 66, which may be local or remote audible or visual alarms, and in addition, may provide, by way of a modem 68 to phone jacks 70, an automatically dialed alarm signal to a pre-established connection. In this manner, it is possible for a person at a remote location to have a call forwarded from the controller 30 indicative of the presence of shut down of the hot water tank 10 coupled with a message indicative of either an alarm condition in general, or a specific message tailored to the particular alarm condition which was sensed by the controller 30 in response to the one or more of the sensors 32, 34, 36 and 38 which created the alarm in the first place.

Figure 1B shows a second embodiment block diagram for monitoring and controlling water consumption in a water-based system.

The interface module system includes two basic circuit modules. The first module is referred to as the interface module. The interface module is a stand-alone, plug-in version which can, but does not need to, plug into the second module, an expansion board known as the interface module motherboard. The inputs and outputs of the plug-in version are monitored/controlled by a microcontroller on the interface module motherboard. Power for the plug-in version is provided by either a

wall outlet (if stand alone) or by the power supplies found on the interface module motherboard (if plugged into it).

Figure 2 is directed to a diagrammatic indication of a modification of the connections to a standard hot water heater, which are employed for providing inputs to the temperature sensor 36 and the pressure sensor 38 in a manner which are not subject to the corrosive effects of water flow in the blow-out pipe 36. As mentioned previously, the pressure relief valve 28 of most hot water tanks undergoes periodic operation during the course of the operation of the hot water tanks 10. This particularly may occur when the hot water tank 10 becomes aged. In any event, when repeated discharge occurs of bubbling water and steam of sufficient pressure to open the pressure relief valve 28, the hard water, scale and other corrosive effects of the water flow through the pressure relief valve 28 over a period of time may cause the relief valve 28 to become sufficiently corroded, as described previously, so that it may not work; or it may require pressure in excess of the designed pressure to operate it. To safely and repeatedly, if necessary, sense excess pressure without subjecting the pressure sensor to the corrosive effects of escaping water or steam, the pipe 26 supplying a connection to the relief valve 28 is fabricated with a generally "X" shaped coupler, as shown in Figure 2. The coupler includes the portion 26 which is connected to the blow-out outlet of the hot water heater. The blow-out relief valve 28 is screwed into the opposite end in a normal manner.

On opposite sides of the pipe 26 and extending outwardly at a 90° angle to the central axis between the outlet 26 and the blow-out relief valve 28, are a pair of outlets 40 and 42. The outlet 40 has a temperature sensor element 36A threaded onto it which includes a bi-metallic operator. This bimetallic operator normally is not in contact with the electrical inlet leads of the sensor 36A. When temperature in

excess of what is considered to be a safe amount by the manufacturer of the hot water tank 10 is reached, the bimetallic element in the temperature sensor 36A pops or is moved to the left, as viewed in Figure 2, to bridge the electrical contacts and to provide an output warning signal of excess temperature to the controller 30 for operating the system as described previously. It should be noted that once the temperature sensor 36A has been operated by an excess temperature, it typically must be replaced with a new sensor, since the bimetallic element has been moved from the position shown in Figure 2 to an operating position, described previously. Generally, such sensors are not re-settable.

On the right-hand side of the fitting shown in Figure 2 is a pressure sensor 38. The pressure sensor element 38A is threaded onto or otherwise secured to the arm 42 of the fitting shown in Figure 2. The sensor 38A includes a pressure activated plunger which is indicated as spring-loaded toward the left of the sensor 38A shown in Figure 2. When pressure in excess of the designed 12 parameters of the pressure sensor 38A is reached, the pressure within the pipe 26/42 forces the sealed diaphragm of the sensor element 38A toward the right to bridge the electrical contact shown to then provide an output signal to the controller 30. When the excess pressure condition terminates, the element 38A returns to the position shown in Figure 2, and the alarm indication is removed.

Figures 3A and 3B are a diagrammatic circuit diagram of the microcontroller 30 and various other connections to that microcontroller for responding to the various sensed parameters which are shown in the block diagram of Figure 1. The microcontroller 30 is supplied with power from the power supply 52, as indicated previously. The power supply 52 includes some or all of the different voltages shown in Figure 3A, namely +12VDC, -12VDC, +3.3VDC, and +5VDC. These are typical

operating voltages for various integrated circuits and are employed in a preferred embodiment of the invention to operate the different sensors 32, 34, 36 and 38, as well as other elements of the system. Some of these voltages are supplied through the microcontroller 30, and others are obtained directly from the power supply 52. The manner in which this is done is conventional, and for that reason, all of the various circuit interconnections have not been shown in Figures 3A/3B.

In the event a power failure should occur, the power supply 52 also is coupled with a backup battery input shown at 82 in Figure 3A. A universal battery charger operated in conjunction with the microcontroller 30 and the power supply 52 is employed, so that in the event there is a failure of the alternating current input at 50, the battery input at 82 continues to operate through the power supply 52 to the microcontroller 30 and other circuit components to maintain operation of the system.

The sensor circuits 32, 34, 36B and 38B are illustrated diagrammatically in Figure 3B. All of these sensors include identical circuitry, operated in response to the respective sensed condition to supply an output signal to the controller 30. Consequently, it is possible to operate the system with a sensing of all of the various parameters which have been described in conjunction with Figure 1, or less than all of them. Whichever system is employed, however, the overall operation with respect to the manner in which the signal is supplied from the sensor to the controller 30 is the same. Each of the sensors 32, 34, 36B and 38B includes a circuit for sensing the interconnection of contacts, such as the contacts described above in conjunction with the leak sensor 32, or with the temperature activated switch 36A, or the power sensor element 38A to supply a signal to the integrated circuit sensor block 32, 34, 36B or 38B. If not all of the sensors shown in Figure 1 are employed, the

appropriate one or more of them may be eliminated. The operation of the remainder of the system, however, is unchanged from that described above.

The LED status indicator 60 also maybe operated in conjunction with a user interface reset 110, as shown in Figure 3A. Typically, the reset includes a reset switch (not shown), which will provide a signal through the controller 30 to re-open the water supply valve 14 and to re-open the gas/electric valve or switch 20 for the heat source of the water tank 10. The user reset also will operate through the microcontroller 30 to reset the LED status indicator lamps to turn on the green lamp 62 and to turn off the red lamp 64. As indicated previously, however, if a temperature sensor bi-metallic switch of the type shown in Figure 2 is employed, it also is necessary to replace the bi-metallic sensor or the alarm condition sensed by the controller 30 will continue to persist, leaving the system in its alarm state of operation.

As shown in Figure 3A, the system also may employ video cameras with built-in sound chips 90, 92, 94 and 96 directed at the water heater or the area surrounding the water heater for providing a monitoring signal to the controller 30 whenever the alarm condition sensed by the microcontroller 30 is reached. Camera 90 (No. 1), for example, could be directed to the area beneath the hot water tank to provide a visual and audible indication of a water leak. Others of the cameras may be directed to different regions around the water tank, or in the room in which it is located, to provide a visual and audible output indicative of whatever area is being scanned by that particular camera. Normally, the cameras 90, 92, 94 and 96 are not turned on. Whenever an alarm condition is sensed by the microcontroller 30, a signal is supplied to the cameras from the microcontroller 30, through a video multiplexer 100, to turn them on, or turn on the one associated with the particular alarm condition

sensed by the microcontroller, depending upon the programming of the microcontroller 30. The video multiplexer 100 also supplies signals through a video amplifier 102 to a digitizer 104 coupled to the microcontroller 30, which then receives the sound and video signals from the camera (or cameras) out of the group of cameras 90, 92, 94 and 96 which has been turned on by the microcontroller 30. The signals from the cameras then are supplied to a video S-RAM 106 for storing the signals temporarily. The video signals may be sent from the microcontroller 30 through a 56K modem 68 to the phone jack 70 in the manner described previously for supplying telephone signals from the modem 68 through the phone jack 70.

The interface module system includes two basic circuit modules. The first module is referred to as the interface module or "breaker" as shown in Figures 4 and 10 discussed below. The interface module is designed to plug into the second module, an expansion board known as the interface module motherboard or circuit panel as shown in Figures 5 and 11 discussed below. The interface module circuitry is identical on both versions. The second embodiment of Figure 1B is accomplished using modular computer aided design (CAD) and modular computer aided manufacturing (CAM) design concepts. While the circuitry is identical, selective loading or placing of groups of parts (modules) on the printed circuit board (PCB) varies from version to version during manufacturing. As an example, the stand-alone version includes a radio frequency transceiver allowing wireless communications with the interface module motherboard. It is included, or CADed in the design of the stand-alone version circuit board, but is not CADed (or added) on the plug-in version. The circuitry for the input sensor on both versions supports three different types of input sensors: 1) a 24vdc digital sensor 2) a 5vdc digital sensor 3) an analog input voltage sensor. Many types of sensors are supported including

leak detectors, flow (volume) sensors, pressure sensors, termpature sensor and level detectors. The color of interface modules molded housing reveals the functionality. While the PCB is the same for each, using modular CAM techniques, the circuitry for each type of input circuit is selectively loaded (installed or placed) on the circuit board as required for each interface module type.

In both versions of the interface module, the output is provided by a single pole double throw (SPDT) relay. The off state of the interface module can be jumper configured for normally open or normally closed. An interface module configured to detect leaks would use the normally open (N.O.) configuration, and close the relay (valve) during an alarm condition (leak detected). An interface module configured to control a lawn sprinkler would be normally closed, opening at a scheduled time to apply water, and closed after a programmed time period or volume had been applied. Likewise, wherein the water-based system includes a tank-less toilet, measurement and control of the water may be metered with a normally closed (N.O.) valve configuration, opening to apply water and closing thereafter for a programmed time period or volume directed through the tank-less toilet system.

The major difference between the stand-alone version of the interface module and the plug-in interface module is the stand-alone version includes an onboard microcontroller and power supply. This allows it to operate without the support provided by the interface module motherboard. The plug-in version does not include either the microcontroller or a power supply. The inputs and outputs of the plug-in version are monitored/controlled by a microcontroller on the interface module motherboard. Power for the plug-in version is provided by the power supplies found on the interface module motherboard.

To provide consistency and familiarity, the design of the interface module motherboard resembles an electrical circuit interface module electrical panel found in a home or business as shown in Figure 11. Each electrical circuit interface module (see Figure 10) in an electrical panel "protects" a branch or area of the home or business from electrical overload or malfunction. The interface module motherboard also "protects" a branch or area of the home or business. The electrical interface module offers protection from electrical malfunction, and the interface module provides protection from water/liquid based overloads or malfunctions.

The layout of the interface module motherboard is much more sophisticated than that found in an electrical interface module panel. The top of the panel is provided with a 256 x 64 dot matrix blue vacuum florescent display (VFD) surrounded by a number of keys (forming a keypad), the sum of which provide a user interface. The user interface allows the user to configure and control many of the functions and options available on the interface module motherboard. Below the display are two rows of eight interface modules. Wires to the inputs and outputs for each interface module run out of the bottom of the unit to the appropriate sensor or valve.

The interface module provides for virtually unlimited system expansion of the number of devices protected. The initial interface module motherboard (known as the master motherboard) provides protection for up to sixteen devices, appliances or systems. Some devices may require two or more interface modules for full protection. As an example, if the protected device has both hot and cold water in feeds, two interface modules would be required to protect the device. Additional expansion is accomplished by simply adding additional interface module expansion motherboards (known as slave motherboards) to the system.

Each expansion motherboard provides protection for up to sixteen additional devices. Up to 100 slave motherboards may be added to an interface module system. A maximum of 1600 devices can be protected per interface module system. The master motherboard communicates with and controls slave motherboards via a private controller area network (CAN) bus. Multiple interface module systems may be connected via a local area network connection. This gives the interface module system a 1 to N correspondence. That is, a single sensor can determine the action of N number of valves. The simplest example is a device with both hot and cold water in feeds. One sensor can control the two valves needed to stop water flow to that device.

The interface module system is based on state of the art microcontrollers, which are in fact complete computers on a chip, or system(s) on a chip (SoC). The microcontroller is completely programmable, allowing new features and functionality to be added at any time, in the field via the Internet. When this feature is combined with the hardware expansion capabilities described previously, the system has virtually unlimited expansion capability.

A graphic user interface (GUI) provides operational information to the user. The display presents real-time display of system status, alarm conditions, configuration options, network (web) status, and power status. The status of each interface module is displayed for a set period of time, one after the other. As an example, if the display time is set for one second, then the status of each interface module is displayed for one second before moving on to the next interface module in line. The user interface also provides a number of keys, allowing the user to set the configuration and operation of each interface module, as well as various operational parameters of the interface module motherboard. Other display options allow

viewing of the status of various interface module parameters for all sixteen interface modules in a system in a single graphic screen format. Accordingly, the malfunction of, e.g., a valve coil or the like, will be informed through the interface module of the system. The graphical user interface thus indicates, for example, when the blowout valve in the hot water tank is inoperable, to permit the user to replace the failed valve rather than the entire water tank. The reason for the water tank failure would be indicated separately, for instance, from identifying leaks and the like, which would require replacement of the tank itself.

The interface module provides a TCP/IP based 10Base-T Ethernet interface. This interface by default supports DCHP protocol for dynamic IP addressing. An interface module master may be connected to either a local area network (LAN, a private network found in the home or company) or a WAN (Wide Area network) such as the Internet (World Wide Web). In addition to visual and audible warnings (internal and optional external buzzers and lights), an email alarm warning can be sent to one or more email addresses programmed by the user. As an example, the home user may program an interface module to send an alarm email to their office, their home, their cell phone and even their plumber. A commercial user can send emails to key management and/or maintenance personnel.

The interface module can receive emails. A text template is included with the interface module system. The user can edit the template and email it to his/her interface module to configure it.

The interface module can be used to host (sever) a web page. This mode of operation is provided to allow security companies that normally monitor homes and businesses for break-ins, to monitor all water appliances from their central office. The web page provides JAVA applets, which allows remote control of the system.

As an example, the security service can issue a (password protected) command to close the main water in feed valve.

Interface module provides both physical and battery (power) backup for a power failure.

Physical backup holds the state of the valves in the event of a system failure. This is accomplished with latching relays. Once the relay is turned on, it will hold its state indefinitely until reset. As long as power is available, the valve(s) will be closed.

The battery backup provided by the interface module allows the system to operate normally during a power failure (optional battery packs allow longer protection). This protection allows interface module to continue to monitor, control, and warn interested parties of a failure.

The interface module provides total, selective, configurable, protection. One sensor can be assigned to protect one or more devices each with one or more valves. Multiple sensors can be configured to protect a single device with one or more valves.

Support for water appliances is virtually unlimited. Any device with water in feed or out feed can be protected and/or controlled. This includes, but is not limited to water heaters, air conditioners, laundry and dish washing machines, toilets, tank-less toilets, ice makers, sinks, spa, swimming pool, sprinkler system, water meters, etc. In the tank-less toilet water-based system the water may be metered to apply water, closing thereafter for a programmed time period or volume directed through the tank-less toilet system.

An interface module can be configured to monitor for leaks, control liquid levels or time the application of liquids. Examples include monitoring the bath tub,

water heater, dishwasher, clothes washer, toilets, sinks and icemaker for leaks, controlling the water level in the spa, swimming pool, and bath tub, and timing the lawn sprinkler on/off times. Water amounts may be monitored by time or volume, such as, for example, to check whether the water company correctly read the meter and whether the lawn or the tree line on the south side of the house was sufficiently or excessively watered. Many cities don't like to see lawn sprinklers with water run-off. Interface modules can be configured to deliver an exact amount of water by the gallon. Herein the water-based system including, e.g., a tank-less toilet, that limits water consumption metered with the electronic valve configuration to control water flow time period programmed or volume directed through the tank-less toilet system.

With reference to Figure 4, the stand-alone interface module circuitry is based on a "state-of-the-art" microcontroller, such as a Cygnal Integrated Products C8051F310 device 111. The F310 is an 8-bit device with an 8051 family central processing unit (CPU) operating at 25mhz, requiring as little as one clock cycle per instruction and instruction cycle time of 40 nano seconds. This means the device is capable of executing a single instruction in 40nsec, or up to 25 million instruction per seconds (MIPS). Seventy percent of the instruction set operates with one clock cycle. The balance requires two, three, or four clock cycles. The device includes sixteen mega bytes of FLASH program memory for storing the control (application) program and non-volatile data and 1280 bytes of random access memory (RAM) for temporary data storage. A total of 29 Input/Output port pins are provided. That means up to 29 input and/or output signals can be connected to the device.

Three different serial port protocols are supported (available concurrently): 1) a standard 9-bit serial port (UART) compatible with PC COMM Ports; 2) a system management bus (SMBus) compatible with the SMBus found on many PC

motherboards used to control a variety of devices found on the board; 3) a serial peripheral interface (SPI) bus used to control addition peripheral devices on a given system. Additional peripheral devices found on the device include 4 timer/counters, 5 programmable counter arrays, 10-bit analog to digital converters with up to 21 channels, voltage comparators, reset manager, software watchdog, brownout detector, missing clock detector, and an internal clock oscillator accurate to 2% and a real time clock. The F310 includes a JTAG interface 112. This provides support for a built-in in-circuit emulator (ICE) for direct program debugging (no expensive external ICE needed), program code download (programming) and boundary layer scanning (for device testing during manufacturing).

When configured as a plug-in version, the interface module includes an expansion connector 113. Many of the control signals used by the onboard microcontroller on the stand-alone version are routed to this connector. This allows a microcontroller found on the interface module motherboard to monitor and control plug-in interface modules in the same manner as the onboard microcontroller on a stand-alone interface module.

These signals include the user reset switch 114 used to reset an alarm condition. An opto-isolated sensor input 115 provides the real-time state of the attached input sensor. The voltage used to power the opto-isolator is jumper configurable to allow a wide range of digital sensors to be used with an interface module. Two jumpers 116, 126 allow the voltage to set to either 24vac or 5vdc. An amplifier 117 is used to detect current flow in the valve control circuit. This allows the system to detect and report a valve coil failure. The sensor input and valve output are routed to a four position, screw terminal block 118. The external sensor and valve are attached to the interface module at this connector. An alarm buzzer

120 is found on the stand-alone version, driven by a PNP transistor driver 119. The plug-in version does not support it. Instead, a single buzzer is found on the interface module motherboard. In addition, up to four external buzzer or warning lights can be attached to the system (see the interface module motherboard circuit description to follow).

A relay is used to drive the valve output 123. The relay is a latching relay. Two control drivers 121 are incorporated in the design, one to latch the relay and one to reset the relay. The latching relay can be configured to provide either 24vac or 24vdc, to allow the use of either an AC or DC valve set by a two jumpers 122, 125. The latching relay has one pole and two contacts. One is normally open and the other is normally closed. A jumper allows the default state of the output to set to either normally open or normally closed. Two status LEDs 130 are found on each interface module. A blue LED flashes to indicate a normal operational state. A red LED will flash during and alarm state.

Additional support circuitry includes a resettable PTC fuse 127 on the AC input. This device opens (trips) if the current flow reached a predetermined level. A 5vdc voltage regulator 128 and a +3.3vdc regulator 129 form an onboard Power Supply for the stand-alone version of the interface module (not used on the plug-in version).

One optional circuit is found on the stand-alone version only. A radio frequency transceiver 131 operates at 912Mhz. It is used to allow "wireless" operation of a stand-alone interface module up to 300 feet from an interface module motherboard.

As shown in Figure 5, the interface module motherboard is a very high integration design provided by no less then ten microcontrollers. At the heart of the

board is a master microcontroller 141, preferably a Cygnal Integrated Product microcontroller, C8051F042. This device is a "Big-Brother" to the F310 device used on the stand-alone interface module. It incorporates the same 25 MIP 8051 central processing unit (CPU) with JTAG interface 142 as found on the F310. It also includes all the features and peripherals found on the F310 plus a large number of addition features. These include expanded onboard FLASH program memory (64K bytes total), expanded random access memory (RAM) (4352 bytes), a larger number of input/output port pins (64 total), a controller area network (CAN) protocol serial port, an additional PC compatible COMM port (UART), and an additional timer and an additional 8-bit analog to digital converter. The F042 also incorporates an external expansion bus, which allows further memory and peripheral expansion "off-chip."

Nine slave microcontrollers are found on the interface module motherboard. The first is a special purpose microcontroller module 143. Referred to as the "network slave," it is designed to provide a TCP/IP based, 10 base-T Ethernet interface, allowing direct connection to a local (LAN) or wide (WAN) area network. It includes 256K of FLASH and 128K of RAM memory onboard. It also incorporates a slave port. This port is connected directly to the master F042 microcontroller's external expansion bus, allowing bi-directional communication between the two microcontrollers. The master sends warning messages across the slave bus (which includes the network address of the recipient) to the network slave, which in turn manages the TCP/IP stack protocol needed to send email warnings over the Internet. Incoming emails are passed to the master via the slave port as well. The network slave also can be configured to serve a "Web status page." The basic web page is retained in the network slave. The dynamic data representing the current

"real-time" status of the interface module system is sent to the network slave across the slave port. The network slave collates the data and places it on the page, serving it to requesting web clients. The sole purpose of the network slave is to manage web based traffic.

In addition to the sixteen plug-in interface modules directly supported on the motherboard, an additional 256 remote interface modules can be monitored and controlled by an interface module motherboard. This is accomplished using a radio frequency (RF) link, or network. A FCC part 68 certified RF transceiver 144 is an option available on the interface module motherboard. Operating at a frequency of 912Mhz, a band of frequencies is set aside for among other things, process control and monitoring, and remote interface modules can be sited as far away as 300 feet.

Each interface module motherboard incorporates a controller area network 145, known in the industry as "CAN." It is intelligent, bi-directional, collision detection, serial communication protocol, commonly used in industrial automation and automotive control applications. The interface module system uses it to link multiple interface module motherboards together to form large systems used in commercial applications.

To allow time/date stamping of alarm warnings, the interface module motherboard incorporates a real time clock/calendar 146. The device includes battery backup to retain current time and date during power failures.

In Figures 6A-D, eight (8) additional slave microcontrollers or module slaves 149 are found on the interface module motherboard. Each is a Cygnal Integrated Products C8051F310, the same device used on the stand-alone interface module. Each interface module slave monitors two plug-in interface modules 150 in real-time. Each interface module slave communicates with the master via the SMBus. When

an alarm condition on any one plug-in interface module is detected, the status is reported to the master. It should be noted that the circuitry is the same for all eight interface module slaves 154, 160.

In Figure 7, a single buzzer 161 is provided on the interface module motherboard. It provides an audible warning of an alarm condition. Four external alarm outputs 165 are available on the interface module motherboard. Up to four external buzzers, bells, sirens or warning lights maybe remotely located with in the boundaries of an installation.

Two master status LEDs 164 are provided on the interface module motherboard. They duplicate the functionality of the status and warning LEDs found on a stand-alone interface module. A blue status LED flashes during normal operation. A red warning LED flashes during and alarm condition.

The interface module motherboard provides a user interface to allow its operation to be configured. A large blue 256 pixel by 64 pixels vacuum florescent display (VFD) 162 provides graphic information on the current status of the system. Twelve keys 163 form a keypad allowing the user to configure the system.

In Figure 8, 24vac power is supplied to the interface module motherboard by a screw terminal 166. A full wave bridge rectifier 168 converts the 24vac to 24vdc. A relay circuit 169 is used by the master to switch the input voltage supply from the 24vac to 24vdc battery backup. Two voltage regulators, one 5vdc and the other 3.3vdc, form a power supply to power the circuitry found on the interface module motherboard. This includes power for 16 interface modules. The master monitors the power supply voltages 172 for normal operation. Voltages outside allowable tolerances generate an alarm condition.

In Figure 9, the interface module motherboard provides 24vdc battery backup for the complete system. This is provided by two 12vdc sealed lead-acid 30 amp/hr batteries connected in series (24vdc). An onboard charger 174 maintains a charge on the batteries. The master microcontroller monitors and controls the operation of the charger. This includes monitoring the charge/discharge current 173, the battery voltage 172, and the current status of the charge cycle 176. The charger can be configured for a number of different battery configurations 177, 178.

The foregoing system is a comprehensive system for monitoring and controlling the safe operation of a water system. Clearly, some components of the system may be employed in other environments than the one described previously. The foregoing description of a preferred embodiment of the invention is to be considered as illustrative and not as limiting. Various other changes and modifications will occur to those skilled in the art for performing substantially the same function, in substantially the same way, to achieve substantially the same result without departing from the true scope of the invention as defined in the appended claims.